

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

CHAIN MOTOR DRIVE CONTROLLER

SPECIFICATION

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a chain hoist motor drive controller which is housed entirely within the casing of a chain hoist to track and control the movement of the load carried by the chain hoist relative to a fixed location.

10 Description of the Prior Art

Chain hoists are utilized in many different applications to raise and lower loads suspending from overhead supports. A chain hoist is comprised of a heavy-duty motor housed within a rugged casing and having at least one chain access opening in the casing.

A chain may be suspended from an overhead support or from the chain hoist itself to carry a load. In either case the chain is routed around a chain drive gear located within the chain hoist casing. The chain drive gear within the casing is driven by the chain hoist motor. The slack portion of the chain, after passing around the drive gear within the casing, is
5 routed back out through the chain opening and hangs from the chain hoist casing as a slack end having a length that varies with the position of the chain hoist casing relative to the overhead support or with the position of the load relative to the chain hoist casing.

The chain hoist motor, through an internal chain drive gear within the casing, pulls either the load or the motor casing vertically upward, or allows the load or chain motor
10 casing to travel vertically downward. The travel of the chain hoist casing or the load vertically up and down is controlled by switches located remotely from the chain hoist casing and coupled to the chain hoist motor by means of an electrical control cable. One or more hooks that are attached to the chain motor casing suspend a load beneath the chain hoist casing. This load is raised and lowered, under the control of the chain hoist operator,
15 by the upward and downward travel of the load or the chain hoist along the portion of the chain which is under tension and from which the chain hoist is suspended. This travel occurs by pulling chain in and paying chain out from the casing. One such conventional chain hoist is described in U.S. Patent No. 2,991,976, while another is described in U.S. Patent No. 3,960,362.

20 Chain hoists are utilized extensively and in widely differing applications. They are used in shops, factories, warehouses, shipyards, and numerous other types of commercial and industrial establishments. In many applications of commercially available chain hoists

the position of the chain hoist motor and casing relative to the length of the suspended chain upon which it travels or the position of the chain which travels relative to it may be controlled merely by observing either the chain hoist itself, or the load suspended from it. Adjustments to the vertical position of the chain or chain hoist may be performed merely by providing manual inputs to the chain hoist control switches. Indeed, a simply manually operated control is sufficiently accurate for many, many chain hoist applications that do not require precise position control.

On the other hand, there are some applications in which precision control of the chain hoist is required. In the theatrical industry, stage sets and props are often moved vertically utilizing general purpose chain hoists, but this movement must be controlled with great precision. For example, different portions of a stage prop may be moved vertically relative to the stage and relative to each other in a closely controlled and intricate sequence and at precise speeds in order to produce special theatrical effects. Precision control of general purpose chain hoists is often necessary in other applications as well. For example, precision control of a general purpose chain hoist may likewise be required at trade shows and expositions in order to create special effects or in order to move interdependent loads in a complex manner. Where precision control of a chain hoist is necessary, visual observation and corresponding adjustment utilizing manual controls is very inadequate and unacceptable.

To provide the necessary precision control for specific applications of general purpose chain hoists, various position-encoding systems have been devised. However, all of these conventional systems have certain drawbacks.

One prior art conventional system is described in U.S. Patent No. 4,905,848. This system employs magnetic sensors on a pulley located externally of a motor in order to provide position information so as to guide the motor to move a load to a proper destination. However, errors are introduced into this system due to stretching of the cable or twisting of the chain, depending upon the load and its orientation. Furthermore, because the system operates at a single speed, there is a jarring or bounce that occurs when the load arrives at its destination and the motor is shut off.

Another prior system is described in U.S. Patent No. 5,790,407. This system employs magnetic or optical sensors located on a cable take-up reel and entails the same problems of discrepancies between the position as sensed by rotation of the take-up reel and the actual position which is determined by rotation of the chain hoist motor shaft. This prior system also operates the motor at a single speed, either full on or completely off. Consequently, the load is subjected to a jarring or bouncing effect both when it is initially moved from a stationary position and also when it arrives at its destination.

Furthermore, the prior systems for operating chain hoists require a considerable amount of hardware and electrical components that must be packed separately and transported separately from the chain hoist itself.

SUMMARY OF THE INVENTION

The present intervention provides a chain hoist motor control system that is housed entirely within the existing casings of the most popular commercially available chain hoists that are most frequently used in moving theatrical equipment. Consequently, the chain hoist motor control system of the present invention is protected from damage and from

being misplaced during transportation and storage. The chain hoist motor control system of the invention is protected by the sturdy casing of the chain hoist and cannot become separated from the chain hoist or misplaced.

Furthermore, the position sensing apparatus for the chain hoist motor controller of the invention is considerably more accurate than conventional systems because the positional information is derived from the chain hoist motor shaft itself through a direct, mechanical connection between the rotary drive shaft of the chain drive motor and the position sensor of the position encoder.

In one broad aspect the present invention may be considered to be an improvement in a chain hoist having a casing housing a bidirectional chain drive motor including a rotary drive shaft within the casing. According to the improvement of the invention a position encoder, including a position sensor, is also located within the casing to produce encoded electrical position signals. In addition, a mechanical coupling is also located within the casing and is joined to transmit rotary motion from the rotary drive shaft directly to the position sensor.

The direct physical coupling between the chain drive motor shaft and the position sensor of the position encoder may take several different forms, such as a meshed gear system or a system of linkages and cranks. Preferably, however, the physical coupling of the chain drive motor shaft to the position sensor is achieved through the provision of a cogged motor pulley mounted on the chain motor rotary drive shaft, a cogged encoder pulley mounted in coplanar relationship with the motor pulley, and a cogged pulley drive belt engaged with both the motor pulley and the encoder pulley.

A pulley and drive belt coupling system is particularly advantageous since in conventional, commercially available chain drives there is a retaining nut at the end of the chain hoist motor rotary drive shaft opposite the chain-engaging mechanism. The kind of motor pulley utilized according to the invention is internally threaded and is engaged on the end of the motor drive shaft in place of the retaining nut. The motor pulley thereby serves the dual function of a retaining nut and also part of the mechanism that transmits rotary motion from the rotary drive shaft directly to the position sensor of the position encoder. By physically or mechanically coupling the movement of the chain drive motor rotary drive shaft directly to the position sensor the system of the invention achieves greater sensitivity to movement and exerts much tighter control over the movement and location of the chain hoist.

The entire mechanical coupling mechanism that transmits rotary motion from the rotary drive shaft to the position sensor is located entirely within the existing casing of the chain hoist. This feature is particularly advantageous since chain hoists of the type utilized in the motion picture industry to move theatrical lighting and other equipment are frequently moved from one location to another. For protection and convenience of handling chain hoists are packed within form fitting shipping cases that have interior, padded surfaces configured to snugly seat the chain hoist casings within the shipping cases. There is no room in the shipping cases for any auxiliary equipment, such as separate housings for a mechanical coupling or a chain motor drive controller. Consequently, such ancillary equipment is typically packed and moved in different containers. However, since such auxiliary equipment is packed and moved separately, there is always the problem of

locating it and reattaching it to the chain hoist once the chain hoist arrives and is to be deployed at a new location. The present invention solves this problem by locating both the mechanical coupling that transmits rotary motion from the rotary drive shaft directly to the position sensor and also the chain motor drive controller physically within the chain hoist casing. This arrangement not only protects the mechanical coupling mechanism and chain motor drive controller from becoming lost or separated from the chain hoist, but also physically protects it from damage since it is housed within the sturdy chain hoist casing.

The chain motor drive controller of the present invention has other very significant advantages as well. The chain motor drive controller of the present invention operates at a variable speed in such a manner as to accelerate rotation of the chain drive motor rotary drive shaft when commencing movement from a stopped position and to decelerate rotation of the chain drive motor rotary drive shaft when the difference between the chain hoist location as determined by the position sensor and the desired destination approaches zero. That is, the driving signals to the chain hoist motor ramp up when the chain hoist is first moved and ramp down as it approaches its destination. Furthermore, the variable speed control of the invention allows the chain motor to creep slowly to a desired destination. This allows a suspended load to be held and moved much more steadily than is possible with conventional chain motor drive controller systems. The present invention avoids shaking or bouncing of the load that is characteristic of conventional chain hoist controllers, particularly at the commencement and at the cessation of repositioning.

In another broad aspect the invention may be considered to be another improvement in a chain hoist having a casing with a bidirectional chain drive motor therein that has a

rotary drive shaft. Specifically, this improvement is comprised of a position encoder located within the casing including a position sensor producing encoded electrical position signals in response to rotation of the drive shaft. The improvement also is comprised of tracking circuitry that is also located within the casing for receiving electrically encoded destination signals from a source located externally of the casing end for receiving the encoded position signals. The tracking circuitry provides electrical encoded motor driving signals responsive to differences between the encoded position signals and the encoded destination signals. The motor driving signals accelerate rotation of the chain motor drive shaft starting from a stationary condition and decelerate rotation of the chain motor drive shaft as the differences between the encoded position signals and the encoded destination signals approaches zero.

Preferably, the electrical encoded motor driving signals of the tracking controller are digital signals and the system also includes an isolation amplifier and converter circuit coupled to receive the digital electrically encoded motor driving signals and convert them to actuating signals. An alternating current drive controller is coupled to receive the actuating signals from the isolation amplifier and converter circuit so as to provide alternating current power outputs to the bidirectional chain drive motor in response to the actuating signals.

The reason for providing the isolation amplifier and converter circuit is that the digital encoded motor driving signals produced by the tracking controller are pulse width modulated, square wave digital signals that have either a "high" or a "low" value. These motor driving signals are at very low voltage and current levels suitable for digital signal

processing, but not nearly great enough for driving the chain drive motor. The isolation amplifier and converter circuit preferably includes optic couplers and in effect serves as an electrical adapter to allow the digital drive outputs from the tracking circuitry to operate the chain drive motor.

5 The chain hoist of the invention is further preferably comprised of a motor brake for preventing rotation of the bidirectional chain drive motor. The motor brake is operated by the alternating current drive controller which applies the motor brake to prevent rotation of the chain drive motor shaft when the differences between the encoded position signals from the position sensor and the encoded destination signals transmitted through the tracking
10 circuitry approaches zero. A brake relay is preferably provided between the alternating current drive controller and the brake to actually operate the motor brake by opening and closing brake calipers or pads.

 A further advantageous feature of the invention is the provision of an encoder-responsive circuit coupled to receive the encoded position signals and the encoded
15 destination signals and connected to the alternating current drive controller and in parallel with the tracking circuitry. The alternating current drive controller responds to the tracking circuitry until and unless the differences between the encoded position signals and the destination signals falls to zero, whereupon the encoder responsive circuit overrides the tracking controller and operates the alternating current drive controller to stabilize and hold
20 the chain drive motor at zero speed until and unless the tracking circuitry receives new destination signals.

 While the tracking circuitry will also hold the chain drive motor at a zero speed

when the chain hoist arrives at its destination, without the encoder-responsive circuit there is a certain amount of "hunting" that can occur which results in a jiggling of the load.

Also, when a new destination is programmed into the system to start operation of the chain hoist motor from a static or stationary condition, there is a very slight delay in the circuit loop through the tracking circuitry. As a result, upon actuation of the chain hoist motor there is a tendency for the chain hoist to drop a short distance, typically about two inches. By overriding the tracking circuitry using the encoder-responsive circuit when the chain hoist is at its destination, both of these problems are largely eliminated.

The invention may be described with greater clarity and particularity by reference to the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view illustrating an improved chain hoist according to the invention.

Fig. 2 is a sectional elevational view taken along the lines 2-2 of Fig. 1.

Fig. 3 is a sectional elevational view taken along the lines 3-3 of Fig. 2.

Fig. 4A is an electrical schematic diagram of one portion of the electrical circuitry of the chain motor drive controller of the invention.

Fig. 4B is an electrical schematic diagram of the remaining portion of the electrical circuitry of the chain motor drive controller of the invention.

DESCRIPTION OF THE EMBODIMENT

Fig. 1 illustrates a conventional general purpose chain hoist 10 of the type widely utilized in the theatrical industry for moving lights, scenery, and other heavy loads. For

example, the chain hoist 10 may be a CM Lodestar one ton Model LL chain hoist sold by Columbus McKinnon Corp., located at 140 John James Audubon Parkway, Amherst, NY 14228-1197. However, it is to be understood that the invention is not limited to use with this particular chain hoist alone, and may be utilized with many different commercially available chain hoists.

The chain hoist 10 has operating components housed within a casing 12 formed of a mating pair of rugged, durable casing shell portions 14 and 16 that fit together and meet at an interface demarcation 18. The casing shell portions 14 and 16 are secured to each other in a conventional manner by screws and bolts (not shown). Together, the shell sections 14 and 16 form an encapsulated casing that houses a heavy-duty, bidirectional, variable speed chain drive motor 20. The chain drive motor 20 has a rotary drive shaft 22, one end of which is visible in Fig. 2. At its opposite end the drive shaft 22 operates a conventional chain-engaging mechanism (not visible).

The chain hoist 10 hangs suspended from an overhead support by means of a length of chain 24 that enters the chain hoist casing 12 from above through a window 26 defined in the casing shell section 16. The length of chain 24 is engaged by the chain-engaging mechanism within the casing 12 so that the chain hoist 10 is held suspended at a desired height. A hook 26 or other attachment mechanism holds a load suspended beneath the chain hoist 10. The trailing tail 28 of the chain emerges from the chain-engaging mechanism within the casing 12 through the window 26 and hangs over an outboard edge of the chain hoist casing 12, as illustrated in Figs. 1 and 2.

When the chain drive motor 20 is driven to raise the load suspended from the hook

26, the chain motor rotary drive shaft 22 is operated for rotation in one direction to advance links of the load-bearing length 24 of chain onto the tail 28 of the chain, thereby causing the chain hoist 10 to climb up the load-bearing length 24 of chain, thus raising the load 12. When the load is to be lowered, the chain drive motor 20 is operated in the opposite direction so that the rotary drive shaft 22 transfers links of the chain from the trailing chain tail 28 onto the lower end of the vertically suspended, load-bearing length of chain 24, thereby increasing that length so that the chain hoist 10 descends down it. The operation of the chain hoist 10 is conventional, and need not be described in great detail.

As illustrated in Fig. 2, the motor 20 is comprised of windings 30 within a generally cylindrical motor housing 32. The distal end of the chain drive motor drive shaft 22 is visible in Fig. 2 and protrudes beyond the intersection of support arms 34 arranged in a cruciform configuration. The end of the chain drive motor drive shaft 22 that is visible in Fig. 2 is externally threaded to receive a conventional retaining nut. However, according to the improvement of the invention the conventional retaining nut is removed and replaced with an externally cogged motor pulley 36, preferably having twenty teeth and a diameter of 1.5 inches.

A cogged encoder pulley 38 also having twenty teeth and of the same diameter is supported on a position sensor shaft 40 that is oriented parallel to and laterally displaced from the chain motor rotary drive shaft 22. A U-shaped mounting bracket 42 supports the position sensor shaft 40 upon a mounting plate 44 that is anchored to the motor housing 32. The mounting plate 44 lies between and is parallel to both the chain motor drive shaft 22 and the position sensor shaft 40. A flexible, cogged or toothed drive belt 46 is engaged in

a loop with both the cogged pulleys 36 and 38. Together, the cogged pulleys 36 and 38 and the cogged drive belt 46 form a mechanical coupling that is joined to transmit rotary motion from the rotary drive shaft 22 to a conventional, optical position sensor indicated at 48 in Fig. 3. It should be noted that all of the components of this mechanical coupling are located entirely within the chain hoist casing 12.

The position sensor 48 forms a part of a position encoder indicated generally at 50 in Fig. 3, which in turn forms a portion of the electrical chain motor drive controller for the chain hoist 10. Many of the remaining components of the chain motor drive controller of the invention are located on the circuit board 52, which is also mounted upon the mounting plate 44 entirely within the casing 12. The primary electrical components of the chain motor drive controller of the invention are illustrated schematically in Figs. 4 and 5.

In addition to the position encoder 50 and the direct mechanical drive coupling including the pulleys 36 and 38 and drive belts 46, the chain motor drive controller of the invention includes a tracking controller 54, a digital-to-analog conversion circuit 56, an isolation amplifier and converter circuit 58, and an alternating current drive controller 60. The chain motor drive controller also includes a motor brake 62, a brake relay circuit 64, a reactor 66, and an encoder responsive circuit 70. There is also an upper limit switch 72 and a lower limit switch 74. The upper limit switch 72 operates to shut off power to the motor 20 when the chain hoist has ascended up the chain to a maximum height established by a limit signal transmitted from a remote computer. The lower limit switch 74 operates to shut off power to the motor 20 when the chain hoist has descended down the chain to a maximum limit established by a limit signal transmitted from a remote computer. All of

these components are located within the chain hoist casing 12.

Brake power and motor power are provided to the chain hoist 10 through an umbilical connecting cable 75 that is attached to the casing 12 by a nine pin plug connection 76, visible in Fig. 1 and illustrated diagrammatically in Fig. 4B. Control signals are communicated to and from the chain motor drive controller of the invention by means of a signal cable 77 that is connected to a conventional computer controller and which interfaces with the chain hoist 10 by means of a nineteen pin signal plug 78, visible in Fig. 1 and indicated schematically in Fig. 4B.

The position encoder 50, which includes the position sensor 48, may be either a magnetic or optical encoder. One suitable encoder that made the employed is the U.S. Digital Encoder, Model S1-1024-B. The encoder 50 produces digital outputs that are amplified and converted by an input/output circuit 80 into two different pulse trains on two sets of signal wires. These two pulse trains are designated Phase A (abbreviated PH A) and Phase B (abbreviated PH B) in the drawings. These two trains of pulses are ninety degrees out of phase and indicate the direction of rotation of the motor shaft 22. That is, rotation of the motor drive shaft 22 in one direction causes pulse train PH A to lead pulse train PH B. Rotation of the motor drive shaft 22 in the opposite direction causes pulse train PH B to lead pulse train PH A. Both pulse trains are transmitted through the signal plug connection 78 and through the signal cable 77 to a conventional remotely located computerized control system. The input/output circuit 80 detects the zero to five volt signals from the encoder 50 and converts them to balanced line signals while filtering out noise.

A destination for the chain hoist 10 is transmitted to the chain motor drive controller of the invention through inputs that are determined by the system operator and provided through a remotely located computer. These destination inputs are transmitted from the computer on wires in the signal cable 77 and are received at the signal plug 78, where they
5 are transmitted to the tracker controller or "tracker motherboard" 54 indicated schematically in Fig. 4B.

The tracker control 54 preferably utilizes motion controlled chip sets, Model MC1401A I/O and MCX1401A CP sold by Performance Motion Devices. The destination signals transmitted to the tracker control 54 are preferably provided as a DMX data stream,
10 which is the standard utilized in the entertainment industry for the lighting protocol for intensity and movement of lights. The tracker controller 54 contains tracking circuitry that receives the digitized electrical position outputs generated by the encoder 50, and processed through the remote computer control system. The tracker controller 54 also receives the destination position signals provided from the remote computer through wires in the signal
15 cable 77 that are received at the chain hoist 10 through the signal plug 78. The tracker controller compares the processed electrical position outputs from the encoder 50 and the destination position inputs from the remote computer and provides drive outputs on line 82 to the digital-to-analog converter 56, labeled "ANALOG BOARD" in Fig. 4B.

Unlike conventional chain motor drive controls, the tracker controller 54 ramps up
20 its drive outputs so as to accelerate rotation of the chain motor drive shaft 22 upon movement of the chain motor drive shaft 22 from a stopped condition to a rotating condition. This gradual increase in the drive outputs avoids a sudden jerking of the load as

the chain hoist drive motor 20 begins to operate from a zero speed condition. The digital drive signals on line 82 are converted to analog signals that increase the speed of rotation of the motor shaft 22 from zero to full speed in either direction, which is indicated by the designation +10 or -10 in Fig. 4B.

5 Conversely, as the tracker control 54 determines that the difference between the position signals received from the position sensor 48 in the encoder 50 and the destination signals commanded by the computer is approaching zero, the digital drive outputs on line 82 to the analog converter 56 decelerate from a value of ± 10 to zero as the actual position of the chain hoist 10 approaches the destination position dictated by the remote computer. 10 The digital-to-analog converter 56 thereby directs the alternating current drive circuit 60 to operate the motor 20 at the designated speed from full foreword to full reverse.

 The tracker control 54 remains in a closed loop feedback control mode of operation throughout, and unlike the prior system of U.S. Patent Number 4,905,848 does not release control and depend upon inertia to bring the chain hoist 10, and hence the suspended load, 15 to the desired position. To the contrary, by operating the motor 20 at a variable speed to accelerate from a stopped condition and decelerate to a stopped condition, the chain motor drive controller of the invention is able to operate the chain hoist 10 with far greater sensitivity and much tighter control than is possible using conventional systems.

 It has proven advantageous, however, to also provide the chain motor drive 20 controller with an encoder responsive circuit 70 that employs operational amplifiers and differential signal photo transistors to form an opto-isolation module that monitors the position of the motor 20 when it is at zero speed. That is, the circuitry of the encoder

responsive circuit 70 in effect looks ahead and “grabs” the motor 20 and overrides the tracking controller 54. It operates the alternating current drive controller 60 so as to stabilize and hold the chain drive motor 20 at zero speed until or unless the tracker control 54 receives new destination signals from the remote computer. The encoder responsive circuit 70 prevents the drive shaft 22 of the motor 20 from slipping when the motor driving signals from the tracker control 54 command the motor 20 to stop all movement.

In the preferred embodiment of the invention illustrated, the isolation amplifier and converter circuit 58, also labeled as a “GO ISOLATION MODULE” in Fig. 4B is coupled to receive the digital electrical encoded motor driving signals from the tracking controller 54 on line 88. The isolation amplifier and converter circuit 58 is employed to provide compatibility between the digital signals received from the tracker controller 54 on line 88 and the input signals that are required for operation of the alternating current drive circuit 60. More specifically, the digital “hi” or “low” driving signals on line 88 are transmitted to an optical isolation logic circuit that turns an LED on and off. The illumination from the LED is received by a photosensitive transistor, which in turn generates or terminates power or “GO” signals on line 90 to the alternating current drive circuit 60. The generation of a signal on line 90 causes closure of contacts in the alternating current drive circuitry 60. The isolation and amplifier converter circuit 58 thereby provides the necessary actuation, or terminates the actuation of the alternating current drive circuit 60 at the level determined by the output of the digital-to-analog converter circuit 56 on line 83.

The alternating current drive circuit 60 is a “torque proving” drive circuit. That is, the alternating current drive circuit 60 makes sure that the motor 20 is energized before it

allows release of the pads of the brake 76.

In the embodiment of the invention illustrated the chain hoist motor 20 is provided with a brake 76 that is operated by the alternating current drive circuit 60 through brake relays on the brake relay circuit card 64. A reactor circuit 66 that includes three inductors is coupled between the brake and power plug 76 and the alternating current drive circuit 60. These inductors smooth out the signals and filter harmonics in the operation of the brake 62.

Undoubtedly, numerous variations and modifications of the invention will become readily apparent to those familiar with chain motor drive controllers. Accordingly, the scope of the invention should not be construed as limited to the specific embodiment depicted and described, but rather is defined in the claims appended hereto.